PALYNOLOGICAL CORRELATION OF THE WESTERN AUSTRALIAN PERMIAN

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Permian successions in Western Australian basins are correlated by palynology, a method that allows stratigraphic correlation of siliciclastic successions in both marine and non-marine facies. The distribution of ten palynological zones in the Perth, Carnarvon, Canning, Officer and Bonaparte Basins reveals sharp differences in stratigraphic distributions and sedimentary thicknesses of coeval units. In the lowest Permian, glacigene units, dated as Asselian to Tastubian, vary greatly in thickness because of pre-existing topography and basin accommodation. Sedimentary thicknesses through the rest of the Permian depend on basin accommodation and vary greatly between, and within, basins. The most striking contrast in stratigraphic thicknesses is between the Merlinleigh Sub-basin with 2700 m of section from the Sakmarian to the Ufimian and the Peedamullah Shelf, where mainly younger Permian rocks of Ufimian to ?Dzhulfian age are present in the subsurface. All basins along the west coast of Australia contain evidence for a stratigraphic break in the mid Permian, probably in the early Ufimian.

PERMIAN rocks are present in the Perth, Collie, Carnarvon, Canning, Officer and Bonaparte Basins of Western Australia, but are overlain by younger rocks over extensive areas (Fig. 1). Where they are concealed, but less than approximately 4000 m deep, Permian rocks are known from boreholes and petroleum exploration wells. In other areas of the Perth, Carnarvon and Bonaparte Basins the Permian is deeper than 4000 m and its presence is inferred by extrapolation from areas with subsurface or outcropping Permian.

Correlation by macrofossils is possible for some intervals in the Perth, Carnarvon and Canning Basins, areas of major importance for Gondwanan correlation because of the relative frequency and Tethyan aspect of the faunas. But significant intervals exist in all basins from which no useful macrofossils are recorded. Data from conodonts, foraminifers, and occasionally macrofossils, can be obtained from boreholes and are potentially useful over intervals with numerous carbonate beds. Currently, eighteen brachiopod zones ranging from the Asselian to the Dzhulfian are recognised from the marine Permian of Western Australia (Archbold & Dickins 1996; Archbold 1993, 1998). However, many faunas occur in isolated, discontinuous, limestone outcrops interbedded with much thicker sandstone and shale sequences and, because of poor exposure, some fossiliferous beds are difficult to place with complete confidence in their correct stratigraphic position. In sections without limestone beds, significant macrofossil assemblages are infrequent. Further collecting will fill in some of the gaps, but only the Merlinleigh Sub-basin holds the prospect of a nearly complete faunal sequence, and only From the Asselian to approximately the Ufimian.

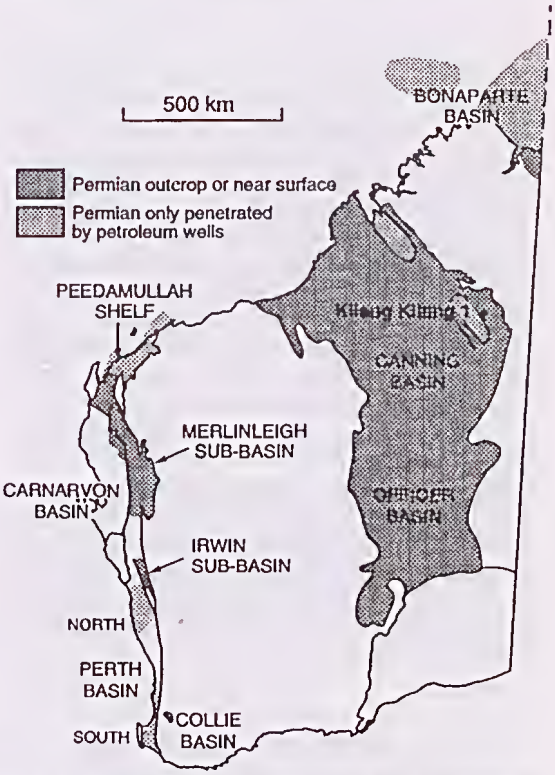

Fig. 1. Western Australia showing areas with accessible Permian rocks.

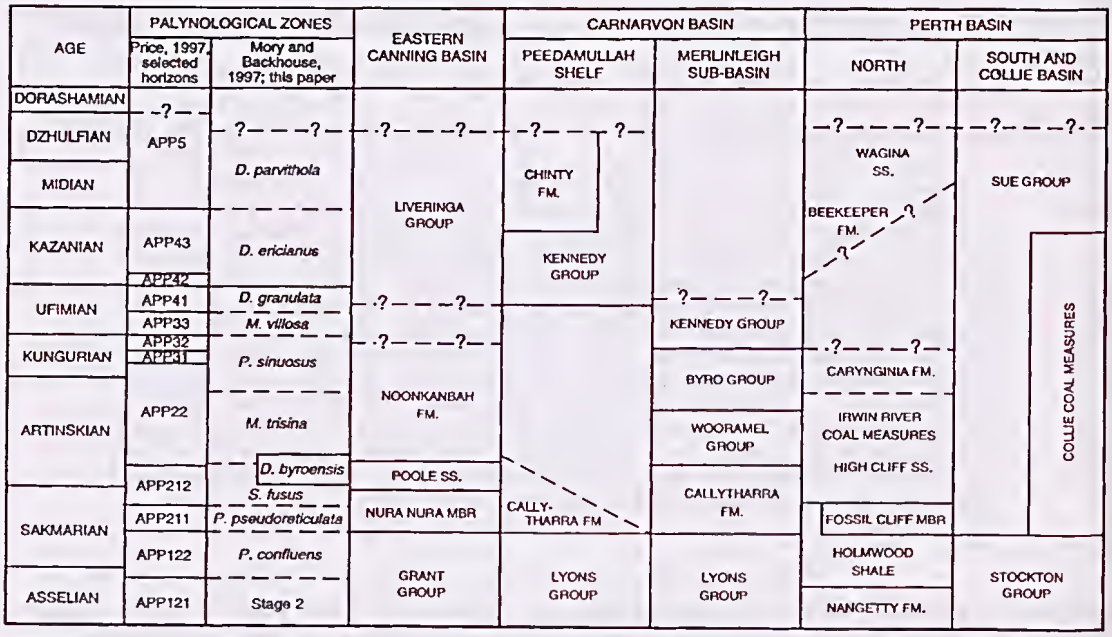

Fig. 2. Correlation of Perth, Collie, Carnarvon and Canning Basin Permian stratigraphic units with palynological zones.

In all basins the the only tool available for correlation of much of the Permian succession is palynology, a method that can be employed in any unweathered, siliciclastic section. Because outcrop throughout Western Australia is usually heavily lateritised, suitable samples are normally obtained only from the subsurface by drilling. Numerous boreholes and petroleum exploration wells that are sufficiently well sampled to allow detailed palynostratigraphic correlation are available from Permian basins along the western Australian margin, from the Perth Basin in the south to the Bonaparte Basin, 2200 km to the northeast (Fig. 1). Intracontinental areas, such as the southern Canning and Officer Basins, are less well served by subsurface exploration, but even in these poorly explored parts some data is available on the Permian. This paper provides a summary of the known distribution and palynological zonal range of Permian rocks in the Canning, Carnarvon and Perth Basins, with brief notes on stratigraphic distribution in other Western Australian basins.

PALYNOLOGICAL SUBDIVISION

Palynostratigraphic schemes for Australia as a whole have been developed since the early work of Evans (1969), principally by Kemp et al. (1977), Price (1983), Price et al. (1997) and Cooper (1991). Localised schemes were published by Segroves (1972) for the Perth Basin and Balme (in Kemp et al. 1977) for the Canning Basin. Many of the biostratigraphically significant datums used in these schemes, notably first appearance datums (FADs), were also used by Backhouse (1991, 1993) for the Collie and Perth Basins, and most recently for the Carnarvon Basin (Mory & Backhouse 1997). All the zonal schemes use some common elements and are, to some degree, interchangeable. The latest scheme of Price (1997) is the most detailed and, although some aspects have been tested only in some eastern Australian basins, application of the numerous correlation points of this scheme will possibly allow finer subdivision in closely sampled sections throughout Australia. Selected parts of Price's zonation, that can be safely correlated with the broader zonation applied here, are shown in Fig. 2. In Australian basins, Permian palynofloras above the glacial units (above the *Pseudoreticulatispora confluens* Zone in Western Australia) show great stability and most taxa are long ranging. Although quantitative criteria have been used in the past for palynostratigraphic subdivision, more recent zonal schemes rely predominantly on first appearances of selected, well

characterised taxa. It is always possible that a zone boundary based on a FAD may be moved slightly lower when better sampled intervals become available.

The zonation used here, based on Backhouse (1991), was presented in its present form by Mory & Backhouse (1997) for the Carnarvon Basin. Ten zones and one subzone are used (Fig. 2), although tighter correlation is possible at an intrabasinal scale. Correlation of the palynostratigraphic units with international stages is achieved by applying macrofaunal and microfaunal ages for selected stratigraphic units to the equivalent, palynologically productive, subsurface interval. In Western Australia, palynomorphs and macrofossils are sometimes, though rarely, available from the same outcrop or core (Archbold 1995a, 1995b) and these occurrences provide valuable data for correlating faunal and palynostratigraphic units. In the Carnarvon Basin careful mapping and correlation with subsurface sections has enabled palynological data from boreholes and petroleum wells to be accurately attributed to stratigraphic units, thus allowing palynological zones to be matched with faunal zones. This has also been done for selected units in the Perth and Canning Basins.

SOUTHERN PERTH AND COLLIE BASINS

Backhouse (1991) identified 10 palynostratigraphic zones in the Permian of the Collie Basin, a small intracratonic basin in the southwestern Yilgarn Craton (Le Blanc Smith 1993). These were correlated with Balme's palynological units from the Canning Basin, the stage system erected for the whole of Australia (Kemp et al. 1977), and Anderson's (1977) zonation for the Karoo Basin of southern Africa.

The southern Perth Basin is closely comparable with the Collie Basin and, like the Collie Basin, is devoid of marine macrofossils, or palynological marine indicators. In both basins the Permian succession above the glacial to proglacial Stockton Group is lacustrine, deltaic or fluvial with numerous coal seams (Le Blanc Smith 1993; Le Blanc Smith & Kristensen 1998). The uppermost 600 to 800 m in Sue 1, in the southern Perth Basin, is younger than the highest beds in the Collie Basin, which do not extend above the *D. ericianus* Zone as used here. Backhouse (1993) recognised two biohorizons in the southern Perth Basin that lie above the *Protohaploxypinus rugatus* Zone, the highest zone recognised in the Collie Basin (Backhouse 1991) and now incorporated into the *Didecitriletes ericianus* Zone. These were the first appearance of *Cannptotriletes warchianus* and an undescribed form of *Microbaculispora*. *Dulhuntyispora parvithola* (Balme & Hennelly) a key species, whose first appearance datum marks the base of the *D. parvithola* Zone and APP5 (Price 1997), is also present in the upper part of the southern Perth Basin succession.

NORTHERN PERTH BASIN

In the northern Perth Basin the glacial and proglacial beds (Nangetty Formation and Holmwood Shale) accumulated to great thicknesses against the Darling Fault on the eastern margin of the basin. The *Pseudoreticulatispora pseudoreticulata* Zone is developed in the Fossil Cliff Formation at the top of the Holmwood Shale (Foster et al. 1985; Backhouse 1993). No palynological data are available from the High Cliff Sandstone, but the Irwin River Coal Measures are no younger than the *Microbaculispora trisina* Zone. The Carynginia Formation has been studied in one borehole (Backhouse 1993) and appears to be no younger than *Praecolpatites sinuosus* Zone.

A significant stratigraphic interval is missing on the northeastern basin margin, on the Irwin Terrace, between the Carynginia Formation and the Wagina Sandstone. The Wagina Sandstone has yielded abundant palynomorphs that belong to the *D. parvithola* Zone. Petroleum drilling in deeper parts of the northern Perth Basin has revealed the presence of units, notably the Beekeeper Formation, which appear to lie stratigraphically between the Carynginia Formation and the Wagina Sandstone. In one well, Beharra Springs 2, Archbold (1995a) identified the *Sulciplica occidentalis* brachiopod zone, and the rather limited palynological data suggest this interval belongs in the *D. ericianus* Zone.

MERLINLEIGH SUB-BASIN

The Merlinleigh Sub-basin in the southeast of the onshore Carnarvon Basin (Fig. 3) contains a considerable thickness of Permian strata and is the key area for faunal subdivision of the Early to earliest Late Permian (Archbold 1993, 1998). The sub-basin contains a great thickness of glacigene Permian rocks, with over 1500 m of Lyons Group estimated in the deepest parts of the sub-basin, along the western margin (Mory & Iasky 1997). The Callytharra Formation, and the Wooramel, Byro and Kennedy Groups are developed to a great thickness and lie above the Lyons Group without a significant break in deposition.

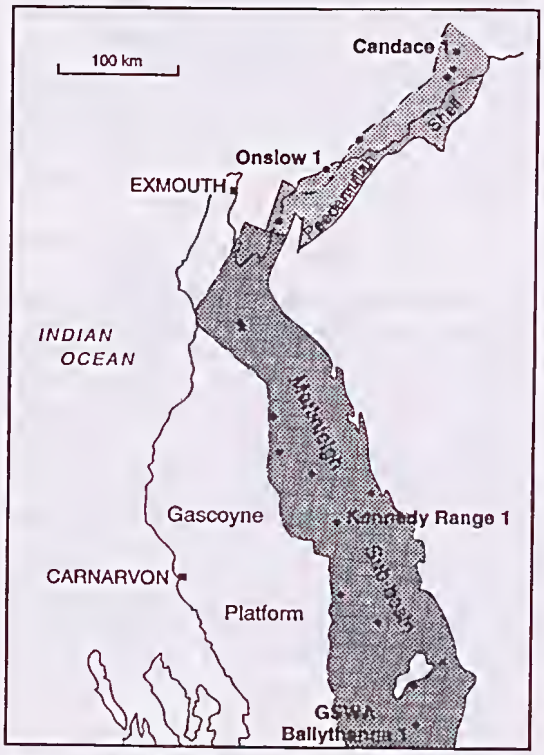

Fig. 3. Permian areas in the Carnarvon Basin showing stratigraphic boreholes and petroleum exploration wells.

The *P. pseudoreticulata* and *Striatopodocarpites fusus* zones, and effectively the lowest levels of the *M. trisina* Zone, are recognised in the extended Callytharra Formation (sensu Mory & Backhouse 1997) in the fully cored section in GSWA Ballythanna 1 (Backhouse 1996). The *Didecitriletes byroensis* Sub-zone is known, so far, only from the Carnarvon Basin, where it occurs in the uppermost *S. fusus* Zone and the lowest *M. trisina* Zone. The *M. trisina* and *P. sinuosus* zones are exceptionally thick, with a total thickness of over 1500 m in Kennedy Range 1 (Mory & Backhouse 1997), an interval that ranges from the base of the Wooramel Group to the lower part of the Coolkilya Sandstone (lowest Kennedy Group). By comparison, the *Microbaculispora villosa* Zone is thin and is present in the upper part of the Coolkilya Sandstone. Palynofloras from all samples examined to date from the Binthalya Formation, and several that may come from underlying Mungadan Sandstone (both higher units in the Kennedy Group), belong to the *D. granulata* Zone. The Binthalya Formation attains a thickness of up to 800 m in the central part of the Kennedy Range.

The *D. granulata* Zone is present in the lowest part of the Kennedy Group on the Peedamullah Shelf, overlying much older Permian units, and therefore there is little overlap of coeval sedimentary units between the two sub-basins.

The ages assigned to the *M. villosa* to *D. granulata* zones are based on correlation with macrofaunal and conodont ages in the Merlinleigh Sub-basin (Metcalfe & Nicoll 1998) and Archbold (1998 and this vol.) should be consulted for a summary of the latest ages assigned to various lithostratigraphic units. In particular the age of the base of the *D. ericianus* Zone has been revised from approximately the start of the Ufimian (Backhouse 1991, 1993) to approximately the base of the Kazanian (Mory & Backhouse 1997). This is based on early Ufimian ages for faunas from the Coolkilya Sandstone, the lowest stratigraphic unit of the Kennedy Group in the Merlinleigh Sub-basin.

PEEDAMULLAH SHELF

The Peedamullah Shelf is separated from the Merlinleigh Sub-basin by an area with Precambrian basement overlain only by a thin interval of Cretaceous and an area in the northern part of the Merlinleigh Sub-basin for which no data are available (Fig. 3). On the Peedamullah Shelf, Permian strata have been penetrated by petroleum wells beneath Cretaceous, Jurassic and Triassic rocks. A description of the thickest Permian intersections is provided by Mory & Backhouse (1997). The Permian in this area is characterised by the absence of most of the Lower Permian. A glacial succession with *P. confluens* Zone, and rarely as in Onslow 1 a slightly younger interval with the *P. pseudoreticulata* Zone or *M. trisina* Zone, is overlain by much younger Permian belonging in the *D. granulata*, *D. ericianus* or *D. parvithola* zones. The complete absence of most of the *M. trisina* Zone and the *P. sinuosus* and *M. villosa* zones is in sharp contrast to the Merlinleigh Sub-basin where this interval attains a thickness of approximately 1500 m. Some of the missing interval may be represented in deeper basinal areas to the northwest, at great depth below the Triassic, and beyond the range of drilling.

CANNING AND OFFICER BASINS

The Canning Basin contains extensive Permian strata, but over large areas only the periglacial Grant Group and immediately younger rocks are represented. Younger Permian units are present in

the Fitzroy Trough and Gregory Sub-basin along the northeastern margin and in other deep basinal areas. Similarly, the Officer Basin contains a thin veneer of glacigene Permian rocks assigned to Stage 2 by Kemp (1976), but possibly including the *P. confluens* Zone in current terminology. Younger Permian rocks have not been identified, to date, in the Officer Basin, which appears to have been particularly stable, with little or no accommodation since the Carboniferous.

Balme's unit subdivision of the Western Australian Permian was established in boreholes and petroleum wells in the Canning Basin (Kemp et al. 1977). Since that time more wells have been drilled and the results from one of these, Kilang Kilang 1, located in the eastern part of the basin, are presented in Fig. 4. This well contains at least 700 m of Permian sandstone and shale above the glacigene Grant Group, which is assigned to the *P. confluens* Zone. A sampling gap that covers the Poole Sandstone accounts for the absence of the *P. pseudoreticulata* and *S. fusus* zones. All samples from the Noonkanbah Formation are placed in the *M. trisina* or *P. sinuosus* zones. The highest sample, just below the top of the formation, contains *Propinquispora praetholus* Price, which has a FAD slightly below that of *M. villosa* (Price 1997). This indicates that the top of the Noonkanbah Formation in Kilang Kilang 1 is in the upper part of the *P. sinuosus* Zone. *Dulhuntyispora granulata* Price is present in the lowest sample from the Liveringa Group and the *M. villosa* Zone appears to be absent. This stratigraphic correlation for the Canning Basin is also shown by Kemp et al. (1977). Failure to identify a zone may be the result of a condensed sequence, or a break in deposition. The close study of other Canning Basin wells with comparable stratigraphic intervals and sampling frequency may resolve this point in the case of the *M. villosa* Zone. The presence of the *Neochonetes* (*Sommeriella*) *nalbiaensis* Zone (Archbold 1998) in the upper part of the Noonkanbah Formation supports a correlation with the upper units of the Byro Group in the Carnarvon Basin.

The Liveringa Group in Kilang Kilang 1 ranges from the *D. granulata* Zone to the *D. parvithola* Zone, with the greatest thickness placed in the highest zone. The presence of *Dulhuntyispora stellata* Price low in the *D. parvithola* Zone in Kilang Kilang 1 suggests that this level may already be quite high in the *D. parvithola* Zone in terms of Price's (1997) zonation. Although Kilang Kilang 1 is located 300 km southeast of the type section of the Hardman Formation, the

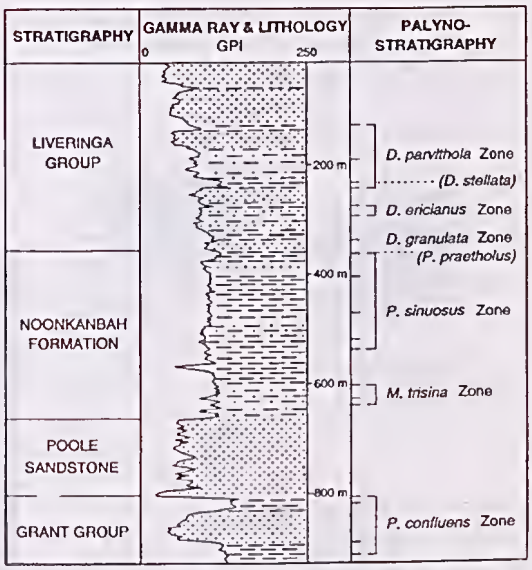

Fig. 4. Correlation of stratigraphy and palynology in Kilang Kilang 1, eastern Canning Basin.

palynological results from wells closer to the type section are known to contain Late Permian palynological assemblages comparable with the *D. parvithola* Zone in this well. Therefore, it is probable that the upper part of the Liveringa Group in Kilang Kilang 1 approximately correlates with the Hardman Formation, which is dated as Dzhulfian on macrofossil evidence (Archbold 1993, 1998).

BONAPARTE BASIN

A considerable thickness of Permian is present in the offshore Bonaparte Basin and although no new work has been carried out it is worth summarising the known palynological data. Mory (1991) provides a palynostratigraphic summary, which relies heavily on the unpublished work of R. Helby and C. F. Foster. In essence, up to 500 m of Upper Permian Hyland Bay Formation (*D. granulata* Zone to *D. parvithola* Zone in the present zonal scheme) overlies up to 600 m of Lower Permian Fossil Head Formation (*M. trisina* to *M. villosa* zones). As in the Canning Basin, it is the *M. villosa* Zone which is absent in some wells. Below the Fossil Head Formation lies the Keyling Formation (*P. confluens* and *P. pseudoreticulata* zones) and the diamictite Treachery Shale. The apparent similarity of this succession with that in the Canning Basin is remarkable.

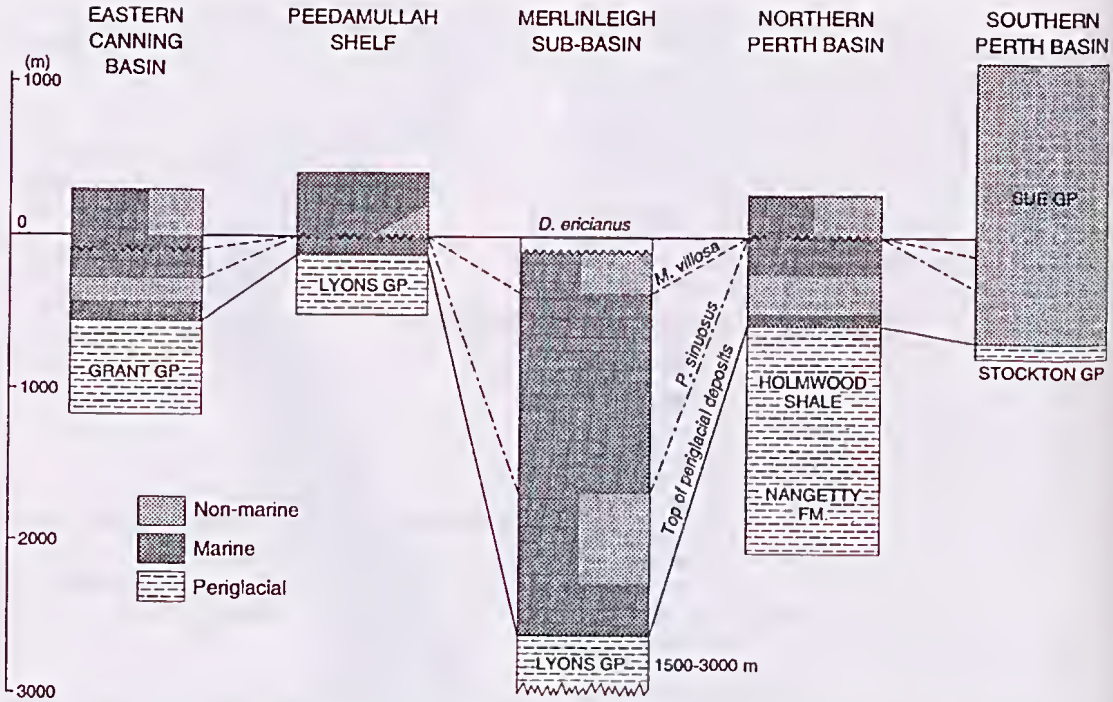

Fig. 5. Comparison of known sedimentary thicknesses against key palynostratigraphic datums in five basin areas in Western Australia.

CONCLUSIONS

Broad, but comprehensive, correlations based on palynomorphs allows comparison of overall rates of sedimentation between basins (Fig. 5). In the southern Perth basin, in the extreme southwest of Australia, up to 1900 m of fluvial coal measures accumulated in the post-Tastubian Permian. The interval in the southern Perth Basin that can be assigned to the *M. villosa* Zone and higher zones (approximately the Late Permian) is significantly thicker than in most basinal areas to the north, although the potential (undrilled) thickness in the Merlinleigh Sub-basin may be significantly greater than that indicated on Fig. 5. The Merlinleigh Sub-basin contains the thickest Permian succession with at least 2700 m of shallow marine sediments, ranging in age from Sterlitamakian to at least Ufimian, deposited in a rapidly subsiding basin. The *M. trisina* and *P. sinuosus* zones (Artinskian to Kungurian) alone total approximately 1500 m. By contrast the Peedamullah Shelf has little Permian of Sterlitamakian to Kungurian age, but up to 500 m (in Candace 1) of sediments estimated to be Ufimian to ?Dzhulfian.

A probable hiatus in the mid Permian (approximately early Ufimian by current age correlations) is expressed by the apparent absence of the *M. villosa* Zone in the Canning Basin and by the partial absence of this zone in the Bonaparte Basin. The *M. villosa* Zone is also part of a much greater interval missing from the Permian succession on the Peedamullah Shelf and, to a lesser degree, in the northern Perth Basin. In the Merlinleigh Sub-basin the *M. villosa* Zone is present in upper part of the Coolkilya Sandstone, but samples from the overlying units can be placed in the *D. granulata* Zone, although palynological determinations from this level in the Merlinleigh Sub-basin are somewhat tenuous because only cuttings samples are available. If a break is present, the most likely position is between the Coolkilya sandstone and the overlying Mungadan Sandstone. Hocking (1998) has recorded such a sequence break at the base of the Mungadan Sandstone in the northern and eastern Kennedy Range. In the southern Perth Basin palynostratigraphic data is sparse over this critical interval. The results from Sue 1, shown by Backhouse (1993), suggest a relatively condensed interval between the base

of the *P. sinuosus* Zone and the base of the *D. ericianus* Zone compared with the Collie Basin, but better sampled sections are available at Collie. In the Collie Basin, Le Blanc Smith (1993) noted an increase in vitrinite reflectance in the middle of the Collie Group, but placed it at approximately the base of the *D. ericianus* Zone, slightly higher than the apparent break in other basins. Therefore, there is evidence for a mid-Permian (possibly lower or mid-Ufimian) hiatus, of at least minor proportions, in each basin along the western margin of Australia.

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